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STUDY ON SHEAR CAPACITY OF CHANNEL AND ANGLE SHEAR CONNECTORS IN COMPOSITE SLAB WITH STEEL DECKING

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ABSTRACT

Comparative study has been performedto know shear capacity of Channel and Angle shear connectors in composite slab with steel decking located between the concrete slab, steel sheet and steel flange.In this study,Abaqus/CAE software is used for modeling 3D-nonlinear finite element model (FEM) of composite slab for analysis of push test. This study utilizes center and favourable position to inspect relative slip, shear capacity and failure mode for replacement of Headed Stud with horizontal Channel and Angle shear connectors. Through finite element analysis, it is observed that Angle and Horizontal Channel connectors have higher shear capacity as compared to Stud connector.

Keywords: *Composite slab, Profile sheet, Channel connector, Angle connector, Headed Stud,Abaqus/CAE, CDP*.

I. INTRODUCTION

In present scenario, composite slab with trapezoidal profiled sheeting is mostly used in construction works. Headed Stud, Channel and Angle shear connectors are utilized to transfer the lateral force from composite slab to steel beam. Slip, failure mode and shear capacity of the shear connectors rely upon the different factors.These factors include position of shear connectors in composite slab, geometry of profiled sheeting and number of connectors used in a rib of profiled sheeting. It is recommended from various design codes and researchers that shear connectors are placed in central position. Though, it is not always practically feasible to place shear connector on central side of the trough.

The push test method is utilized to examine the performance of shear connectors in composite slab using FE analysis (Finite Element Analysis) in commercial software Abaqus/CAE. It is a software used to solve various difficult problem including complicated geometry, loadings and material properties by using FE analysis.

Ellobody& Young [1]studied the composite beam with profiled sheeting to know performance of shear connection.The European Code, British and American specifications overestimated the capacity of shear connection with a maximum percentage value of 11, 25 and 27, respectively.Nguyen & Kim [2]performed the push out test to find out the capacity of Headed Stud connectors embedded in a slab. The FE analysis results were verified with experiment results. Rehman et al. [3]performed push-off test to study stiffness, shear strength and ductility of shear connectors in composite slab. With the increase of concrete strength, ultimate shear resistance increases whereas ductility of connector decreases. Pandya et al. [4]developed FE model of composite slab. Analytical study is carried out to achieve quasi-static solution. It is observed that shear resistance capacity of Channel connector increases by 33.66% and 34.03% at 0º and 90º, respectively by replacing Headed Stud with Channel connector. Similarly, shear resistance capacity of Tee connector increases by 11.37% at 0º and decreases by 12.84% at 90º by replacing Headed Stud with Tee connector.

Push test set up

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Figure 1 shows arrangement of push test. Two HeadedStud connectors of 19 mm diameter&100 mm long are located on the central side of the trough. Welding is provided through flange of steel beam using section of 254×254×89 UC to the deck.

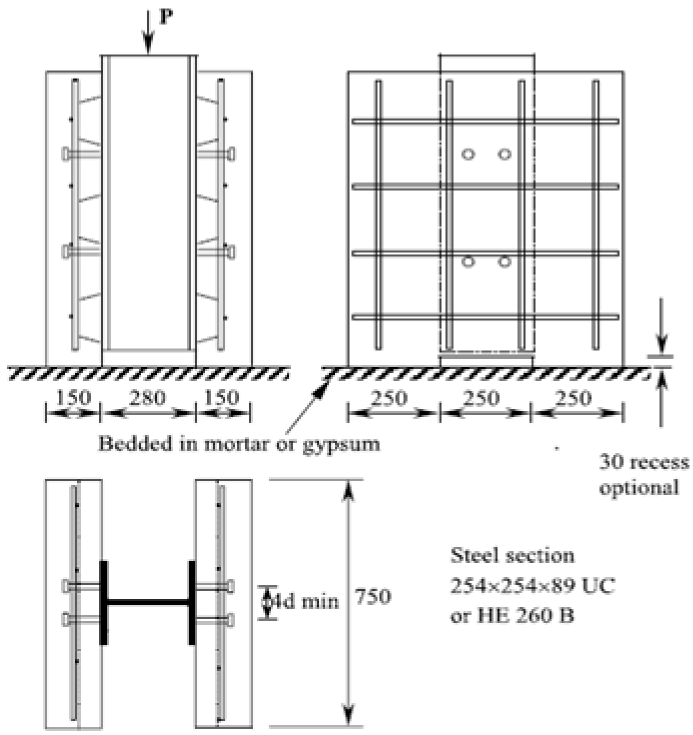

Figure 1Push test on composite specimen with transverse sheeting (Qureshi et al. [5])

II. VALIDATION

General

A pre-processor 3D-nonlinear FE model of composite slab is developed by using Abaqus/CAE for the push test. For the quasi-static solution of FE model, slow rate load application is used. For the analysis of the push test model, suitable application of materials, boundary conditions, interactions and loadingare specified. Figure 2 shows the geometry of profile sheet and Figure 3 shows the elevation of HeadedStud.

Geometry and Assembly

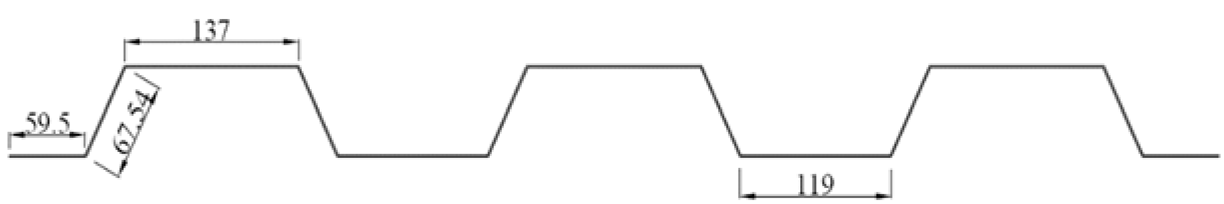

Figure 2 Geometry of profile sheet with thickness of 0.9 mm
(All dimensions are in mm)

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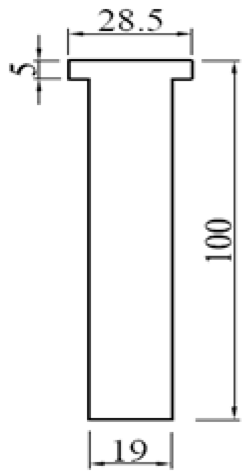

Figure 3 Elevation of Headed Stud (All dimensions are in mm)

The geometry of the push test is developed by assuming a quarter symmetry at the center line of the steel beam web. Only the flange of beam is modeled and the web is ignored in modelling as geometry of the steel beam is not a part of interest as shown in Figure 4. C3D8R 8-Node brick type element meshing is applied to Headed Stud, concrete slab, profile sheet and steel beam.

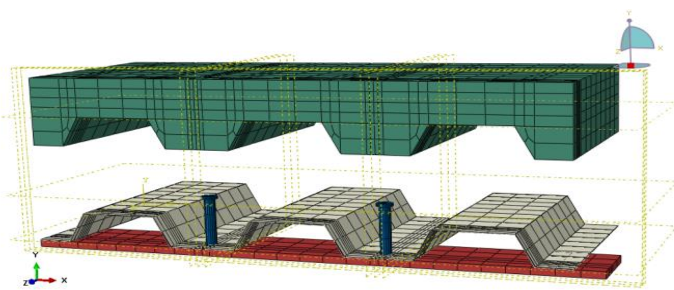

Figure4 General arrangement of all components for FE analysis

Load application and boundary conditions

Loading surface and boundary conditions are provided as similar as defined in the study of Pandya et al. [4] as shown in Figure 5. Surface 1 is restrained to displace in Z-direction, surface 2 is restrained in all directions and displacement is applied to surface 3 with help of smooth amplitude application.

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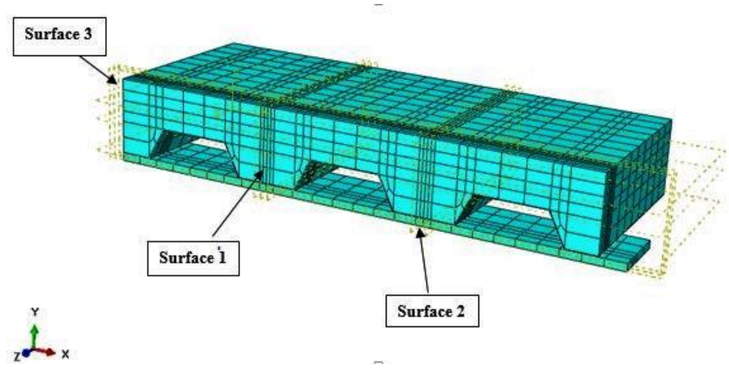

Figure5 Loading and boundary condition

Contact interaction and Constraints

All the parts are combined to form assembly and provided appropriate contact interaction and tie constraints. Contact interaction and tie constraints are as similar as defined in the study of Pandya et al. [4]. Surface to surface contact interaction is applied to concrete slab and profile sheet, concrete slab to Headed Stud and profile sheet to steel beam flange. Tie constraint is provided between Headed Stud to profile sheet and Headed Stud to steel beam flange.

Material property of Concrete slab

Concrete damage plasticity (CDP) model is utilized for the concrete slab. Behavior of concrete is well-defined in the terms ofdensity and elastic properties. According to BS EN 1992-1-1 [6] provision the elastic property are defined. All the values of compressive and tensile properties are taken from Qureshi et al. [7].

Material properties for profile sheet, steel beam and Headed Stud

The modulus of elasticity of profile sheet and Headed Stud are 200 GPa. The yield stresses for Headed Stud and profile sheet are 470 MPa& 350 MPa and density forall steel components are 7800 kg/m^3.

Result of Validation

For validation work, FE model of push test for quarter symmetric portion is verified with the analytical results (Pandya et al. [4]). The FE stress results of Headed Stud is shown in Figure 6. The shear capacity, failure mode and slip behavior of Headed Stud has been investigated. Figure 7 showssimilarity in elastic-plastic behavior with error of 4.79 %.

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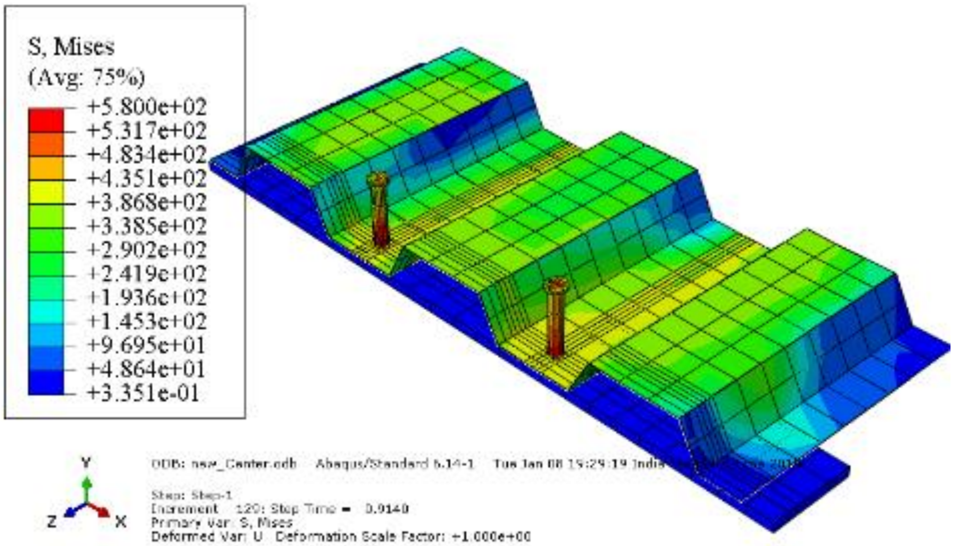

Figure 6 FE stress result of Headed Stud

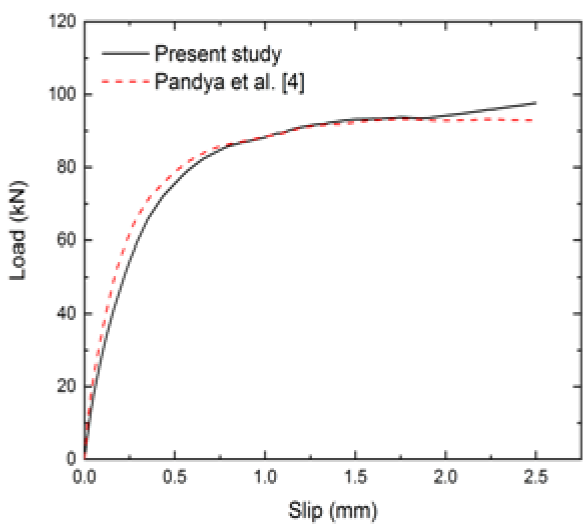

Figure 7 Comparison of analytical and research paper results load versus slip behavior of push test with Headed Stud at center position (Pandya et al. [4])

Table 1Comparison of load versus slip results of present study with Pandya et al. [4]

	Ultimate load (kN)	Relative slip (mm)	Diff. (%)
Present study	97.66	2.5	4.79
Pandya et al. [4]	93.2	2.5	

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III. PARAMETRIC STUDY

In this study, the developed FE model is utilized to analyze the shear capacity, failure modes and slip behavior of Channel connector and Angle connector which are placed at different position of profile sheet. Further study on replacement of HeadedStud with Channel and Angle connectors with different position areperformed to investigate relative shear capacity, failure mode and slip.

Material property of concrete slab

For the concrete slab,CDP model is used. The behavior of concrete is well-defined in the terms of plastic and elastic properties for tensile& compressive strength of M20 grade concrete. As per BS EN 1992-1-1[6] provision of elastic property are defined. Density and Poisson's ratio of concrete slab are taken as 2400kg/m^3 & 0.2, respectively with depth of 180 mm. The dilation angle is taken as 40˚, while other plasticity parameters are assumed. Compressive strength, f_{cm} is 20.6 MPa as shown in Figure 8. Figure 9shows tensile stress and Figure 10 shows tensile damage parameters (Qureshi et al. [7]).

Material properties for profile sheet, steel beam, Angle and Channel connectors

The modulus of elasticity of profile sheet, Angle and Channel connectors is 200 GPa. The yield stress for Angle and Channel connectors is 470 MPa and profile sheet is 350 MPa, and the density for all steel components are 7800 kg/m^3.

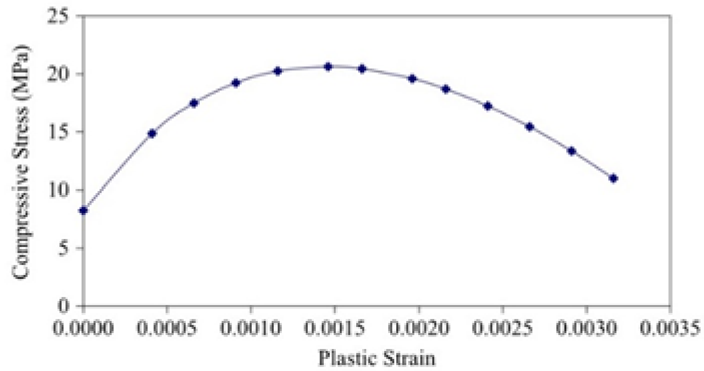

Figure 8 Compressive stress versus plastic strain curve for concrete slab (Qureshi et al. [7])

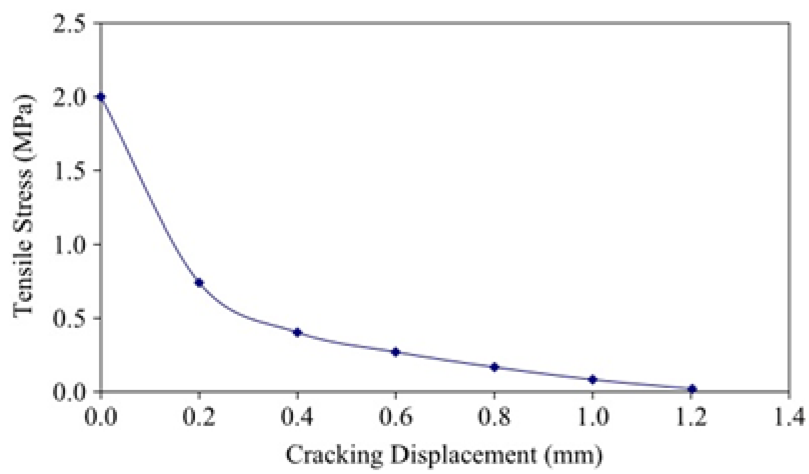

Figure 9 Cracking displacement versus tensile stress curve (Qureshi et al. [7])

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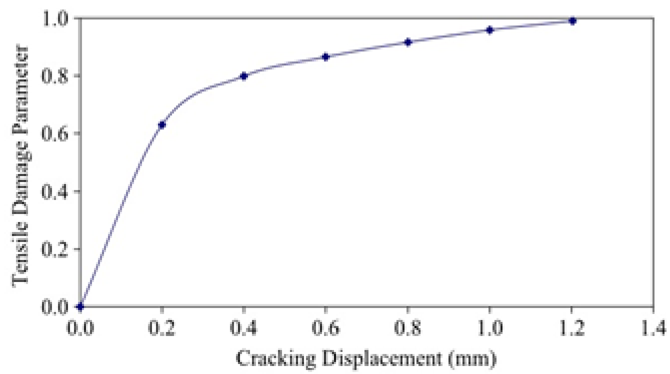

Figure 10 Cracking displacement versuss tensile damage parameter curve (Qureshi et al. [7])

IV. FE MODEL

Geometry of Channel and Angle connectors

Figure 11 shows the geometry of Channel connector and Angle connectors developed using the FE software Abaqus/CAE. Channel connectors are connected through profile sheet to steel beam flange where thickness of profile sheet is 0.9 mm and section of steel beam flange is 125×14.2 mm and 1000 mm long. Similarly,Angle connector is also connected to profile sheet and steel flange. The concrete slab is provided with depth of 180 mm. C3D8R 8-Node brick element is used for meshing concrete slab, profile sheet, Channel connectors, Angle connectors and steel beam flange. Four models are developed with different position of Channel and Angle connectors with height of 200 mm as shown in Figures 12-15

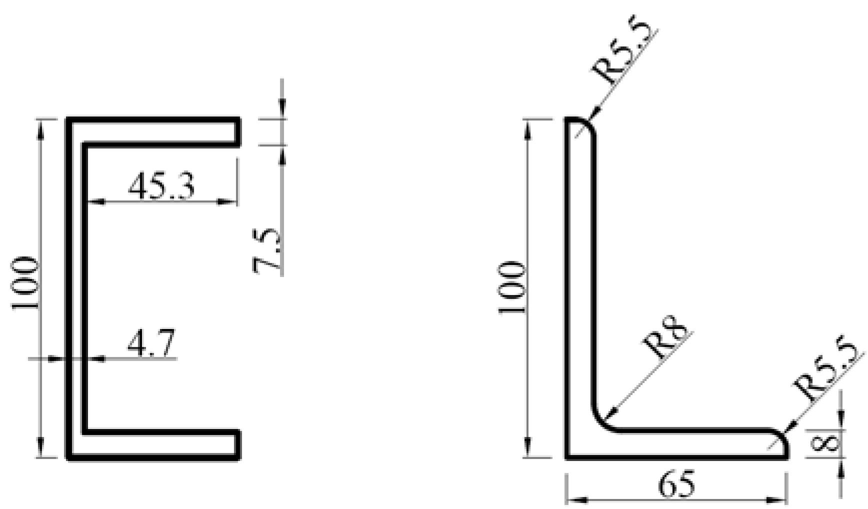

Figure 11 Geometry of Channel connector and Angle connector (All dimensions are in mm)

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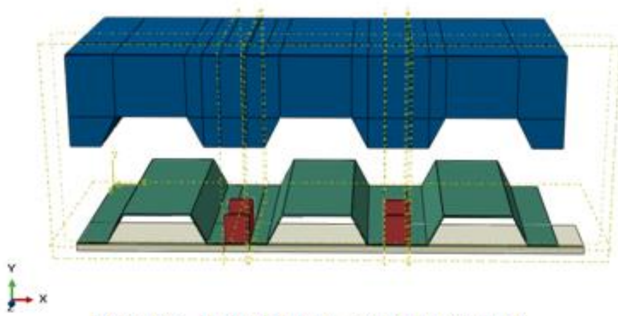

Figure 12 Assembly with center position of Channel connector

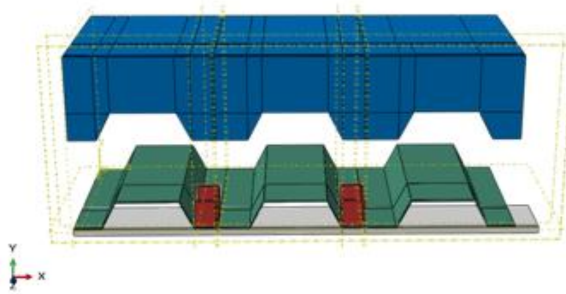

Figure 13 Assembly with favourable position of Channel connector

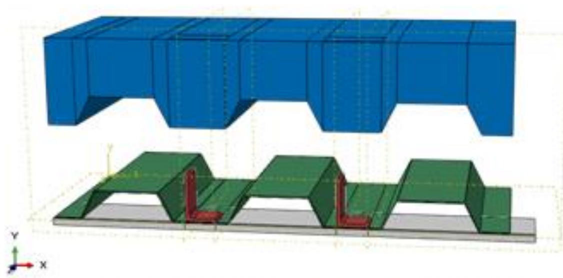

Figure 14 Assembly with center position of Angle connector

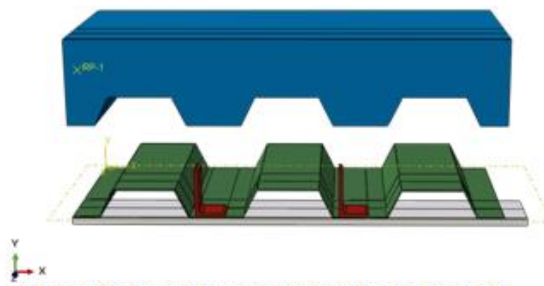

Figure 15 Assembly with favourable position of Angle connector

Boundary conditions and Loading

Loading surface and boundary conditions are already depicted in Figure 5 for push test. The bottom surface of steel-beam denoted as surface 2 is restrained in all direction. The surface1 in which the nodes of profile sheet, steel beam and concrete slab are restrained to displace in Z-direction. The push test is carried by applying displacement on the surface 3 of deck in positive X-direction.

Interactions and Constraints

All the parts are combined to form assembly which provides suitable contact interactions andtie constraints. Welding application is implemented in FE model by tie the surface of the profile sheet around Channel and Angle connectors. And also tie constraint is used to connect at the bottom surface of channel and angle connectors with the top surface of steel beam flange. Surface to surface contact is applied between the concrete slab and profile sheet by using the contact pair algorithm method. The same contact application is used between the concrete slab with Channel connector as well as Angle connector. Frictional penalty is applied to top of steel beam flange and bottom of profile sheet as 0.5, and the normal behavior is given as “hard contact” to prevent the penetration.

V. RESULTS AND DISCUSSION

Results are evaluated in terms of load versus slip curve by replacing Headed Stud with Channel and Angle connectors at different positions. Load and slip results are obtained through FE analysis of Channel and Angle connectors with different position and then compared to Headed Stud. The analysis result for shear resistance per Headed Stud is 97.66kN at 2.5 mm slip. Shear resistance per Channel at central position is 165.57kN at 2.5 mm slip, and at favourable position is 163.98kN at 2.5 mm slip. The analysis result for shear resistance per Angle at central position is 126.80kN at 2.5 mm slip and at favourable position is 89.79 kN at 2.5 mm slip. Table 2 shows values of load-slip for all connectors and Figure 20 shows compression graph and Figures 16 & 17 show the FE stress results of Channel connector and Figures 18 & 19 show the FE stress results of Angle connector.

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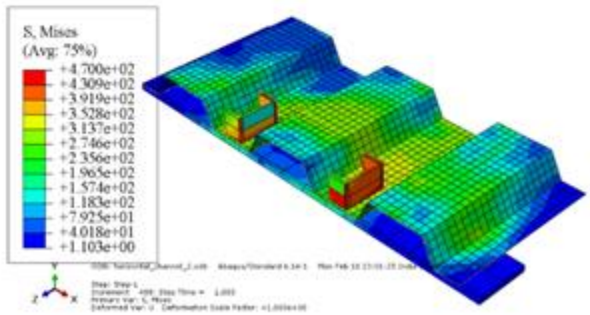

Figure 16 FE stress results of Channel connector at center position

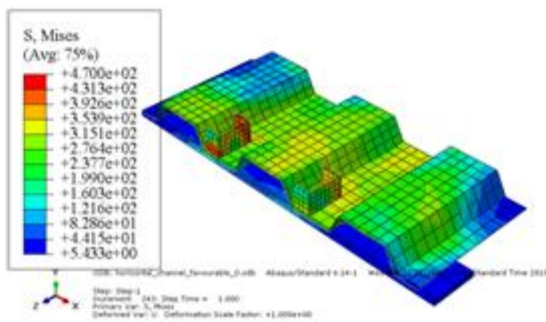

Figure 17 FE stress results of Channel connector at favourable position

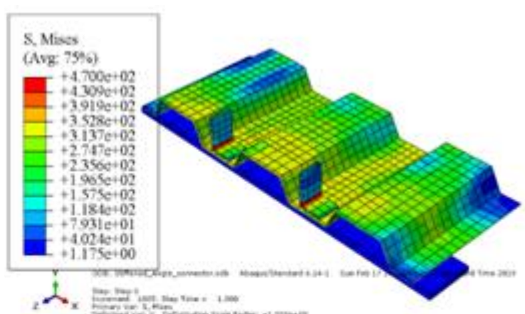

Figure 18 FE stress results of Angle connector at center position

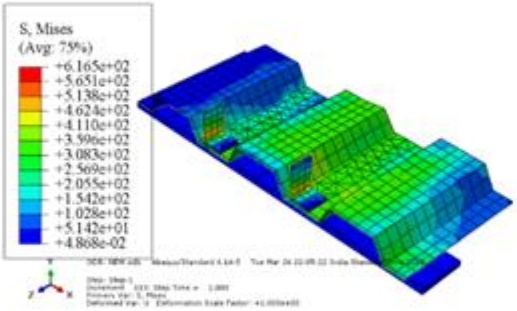

Figure 19 FE stress results of Angle connector at favourable position

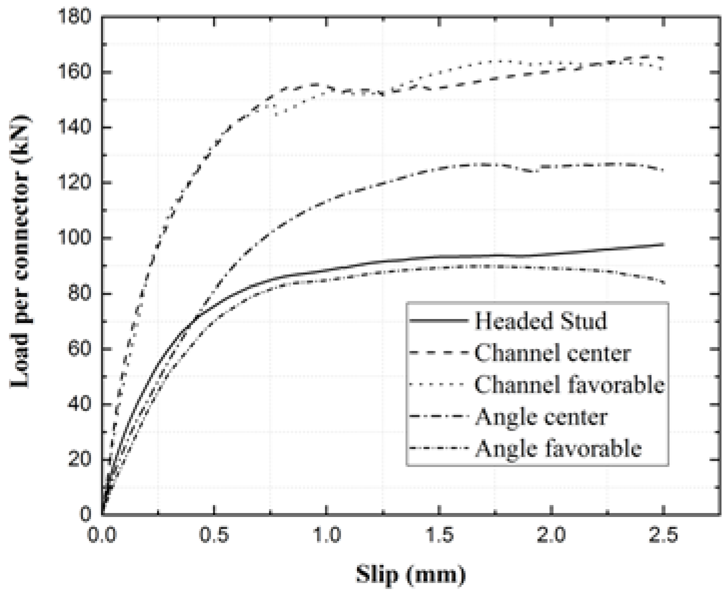

Figure 20 Comparison of analytical results of load versus slip behavior of Headed Stud, Channel and Angle connectors at central and favourable positions

Table 2 Load-Slip Results

Connector	Position	Ultimate Load (kN)	Relative Slip (mm)
Channel	Center	165.57	2.5
	Favourable	163.98	2.5
Angle	Center	126.80	2.5
	Favourable	89.79	2.5
Stud	Center	97.66	2.5

VI. CONCLUSIONS

As per the analytical results by replacing the Headed Stud with Channel connector, it is observed that shear resistance capacity of Channel connector increases by 41.02 % and 40.44 % at center and favourable position, respectively. As per the analytical results by replacing the Headed Stud with Angle connector, it is observed that shear resistance capacity of Angle connector increases by 22.98 % at center position and decreases by 8.76 % at favourable position. According to analytical results, it is observed that shear capacity, slip and failure mode of Channel connector show betterment compared to Headed Stud and Angle connector. Load versus slip behaviour of Channel and Angle connectors with center position has higher load carrying capacity as compared to favourable position. It is observed that Channel connector with center position show highest energy absorption capacity as compared to other shear connectors.

REFERENCES

1. *Ellobody E., Young B. (2006) "Performance of shear connection in composite beams with profiled steel sheeting", Journal of Constructional Steel Research, Vol. 62, pp. 682-694.*
2. *Nguyen H. T., Kim S. E. (2009). "Finite element modeling of push-out tests for large stud shear connectors", Journal of Constructional Steel Research, Vol. 65, pp. 1909-1920.*
3. *Rehman N., Lam D., Ashour A. F. (2016). "Experimental study on demountable shear connectors in composite slabs with profile decking", Journal of Constructional Steel Research, Vol. 122, pp. 178-189.*
4. *Pandya Y. K., Panchal V.R., Patel N. A. (2017). "Study on shear capacity of different type of shear connectors in composite slab with steel decking", A National Conference on New Horizon in Civil Engineering, Surat, Gujarat, India.*
5. *Qureshi J., Lam D. and Ye J. (2011). "The influence of profiled sheeting thickness and shear connector's position on strength and ductility of Headed shear connector", Engineering Structures, Vol. 33, pp. 1643-1656.*
6. *BSEN1992-1-1 (2004). "Eurocode 4: Design of composite steel and concrete structures - Part 1-1: General rules and rules for buildings", London: British Standards Institution.*
7. *Qureshi J., Lam D. and Ye J. (2011). "Effect of shear connector spacing and layout on the shear connector capacity in composite beam", Journal of Constructional Steel Research, Vol. 67, pp. 706- 719.*